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The development of a truck concept to allow improved direct vision of vulnerable road users by drivers

Steve Summerskill*, Russell Marshall

Loughborough Design School, Loughborough University, Loughborough LE11 3TU, United Kingdom

Abstract

The paper describes a research project which examined the potential benefits of increasing the allowed lengths of heavy goods vehicles in Europe to foster improved aerodynamics and safety. A concept vehicle was analyzed using the SAMMIE Digital Human Modelling system through the use of a novel technique which allows the volume of space visible to drivers to be visualized and quantified. The technique was used to quantify the size of blind spots for the concept vehicle and a baseline existing vehicle. This concept was then further iterated to improved direct vision from the cab. The results indicate that the addition of aerodynamic front sections to existing vehicle cabs has minor benefits for improved direct vision from vehicle cabs, and that other modifications such as the addition of extra window apertures and lowering the vehicle cab with reference to the floor, have benefits in terms of allowing the driver to identify VRUs in close proximity to the vehicle.

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1. Introduction

This paper reports aspects of research project funded by Transport for London (TfL) and Transport & Environment (T&E) and performed by members of the Design Ergonomics Group (DEG) at the Loughborough Design School (LDS). TfL is the local government body responsible for most aspects of the transport system in Greater London in England. T&E is body that campaigns for smarter, greener transport in Europe. The project

* Corresponding author. Tel.: +44(0)1509228313.
E-mail address: s.j.summerskill2@lboro.ac.uk

research phase highlighted that the recent growth in cycling in London has been accompanied by concerns about cyclist safety. Recent research [1] confirms that whilst there has been a general improvement in road safety in the UK with casualties falling 49% between 2000 and 2012, and the numbers of those killed and seriously injured (KSI) falling 40% in the same period, cyclist casualties have not followed the national trend. Data shows that over the same period the numbers of killed or seriously injured cyclist casualties have increased by 21% nationally and in Greater London by 59%.

Further increased rates of cycling resulting in increased exposure are expected to result in an increase of cyclist casualties unless levels of risk can be reduced at a greater rate. With this background the aim of the project was to examine potential improvements to Heavy Goods Vehicles (HGV, Category N₃, with a gross vehicle weight in excess of 12tonnes). These vehicles, and construction variants in particular, have been identified as being disproportionately associated with accidents with cyclists, [1,2,3] and other Vulnerable Road Users (VRUs). The commissioners of the project were motivated by the discussions being held by the European Parliament in 2014 that involved allowing an increase in HGV length in order to allow aerodynamic features to be added to vehicles, along with the potential to improve safety. The European standard that governs vehicle length is 96/53/EC and it a revision to this standard that was being proposed. Previous research sponsored by T&E [4] resulted in a concept truck cab design (FKA concept) with optimization for aerodynamics and pedestrian protection in the form of improved underrun protection. The DEG team was commissioned to explore the potential benefits of this design in terms of improved direct vision using techniques established in previous research performed for the UK Department for Transport to quantify both direct vision (through windows) and indirect vision (through mirrors) [2]. In addition it was requested that further iterations of the vehicle design should be produced to improve direct vision further where possible. The assessment and analysis technique uses the SAMMIE CAD Digital Human Modelling (DHM) system and novel projection technique which allows the volume of space visible to the driver through windows and mirrors to be visualized and quantified [5]. The following paper describes the methodology and results from the analysis of direct vision from the FKA concept vehicle compared to a baseline existing HGV, and a key iteration of the FKA concept which was found to be the most successful of three produced during the project. The direct vision from the cab was the focus of the research due to the findings of previous research [2] which demonstrated the potential difficulty that a driver has in using six mirrors, in combination with direct vision, in order to generate situational awareness of the location of VRUs. The full results can be reviewed in the project report [3].

2. Methodology

2.1. FKA concept vehicle setup in the DHM system

The FKA concept vehicle design and analysis [4] focused upon the aerodynamic and underrun protection features of a vehicle cab. The concept design did not have a Driver Accommodation Package (DAP, i.e. seat, steering wheel or pedals) defined. In order to perform an analysis of the direct vision using the techniques available in the SAMMIE DHM system, an eye point definition is required. In order to establish an eye point the driver accommodation package must be simulated in the DHM system.

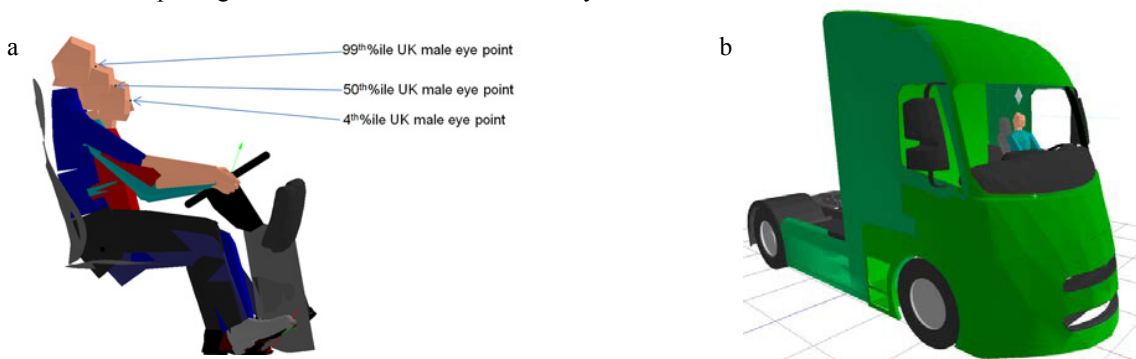


Fig. 1. (a) The DAP showing the variability in eye points (b) The DAP and associated dash board installed in the FKA concept.

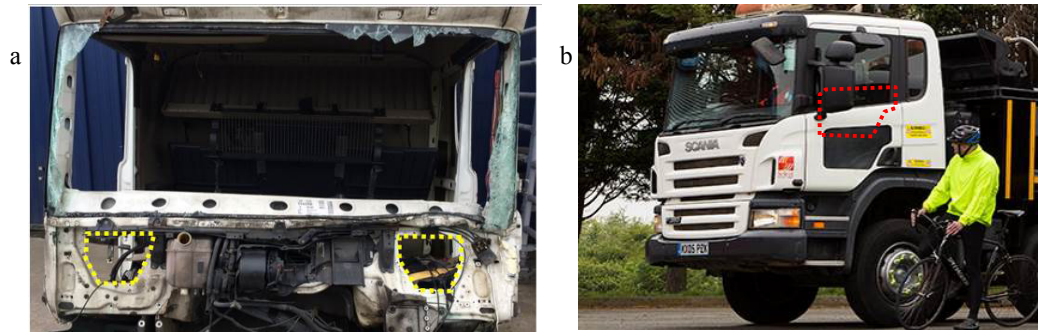


Fig. 2. (a) A stripped vehicle, showing the apertures in the structure which allow the routing of electrical wiring (b) The additional window below the passenger window which is currently being tested by some UK operators.

With no package installed in the FKA concept the driver accommodation package of the DAF XF 105, which had been digitized in previous research [2] was added to the FKA concept including the dash board structure to allow the simulation of obscuration provided by this. The variability in driver's eye location due to the variability in driver size is usually represented in the vehicle design and assessment process using the Society of Automotive Engineers (SAE) Eyellipse (a contraction of eye and ellipse) data. These Eyellipses are produced by capturing the eye position from a large sample of drivers in specifically designed experiments as described by Reed [7]. However, as also described by Reed [7], the current SAE Eyellipse data (SAE J941) is not applicable to modern goods vehicle designs as the data does not account for height adjustable seats. The three eye positions shown in Figure 1 were therefore defined by postures and body size data captured from truck drivers in previous research performed by the LDS team [2], and validated using an Eyellipse that was generated using techniques reported by Reed [7]. It should be noted that only results for the 50thile UK male are shown in this paper.

2.2. The iteration of the FKA concept to improve direct vision

The project required that the FKA concept should be redesigned to further improve direct vision. Therefore strategies for the improvement of direct vision were defined based upon research involving the development of an understanding of the vehicle structure and how extra window apertures could be added to the vehicle to support the direct vision of vulnerable road users. Figure 2a shows a stripped vehicle cab, allowing the visibility of apertures (yellow dotted lines) that are used in the structure to allow electrical connections to be routed through the vehicle. This established that apertures in the vehicle frame can be implemented without affecting the structural integrity of the cab crash cell. This was reinforced by discussions with vehicle manufacturer representatives who were aware of the potential to move electronic systems to the rear of the cab in future design iterations. Figure 2b shows a modification to an existing cab design with a window (red dotted line) being placed below the passenger window to improve direct vision of VRUs. At the time of writing, this modification is being tested by a number of vehicles operators in the UK.

It was therefore established that it is feasible to add extra windows below the line of the existing windscreen. In addition to this modification the FKA concept was also lowered in height. The height of the FKA concept was based upon an analysis of existing vehicle design [4], however by analyzing the height variability in existing vehicle designs that is possible through the combination of different suspension systems and axle configurations it was determined that a reduction in height of 230mm was possible. This height reduction has the potential to reduce the off road capability of the vehicle due to reduced ground clearance, but improve direct vision. Therefore the FKA concept was redesigned to lower its height, add windows to the structure below the windscreen, and to add windows below the passenger door window. The windows which were added below the windscreen were blocked from the vision of the driver by traditional dash board designs. Therefore a further design change was made in the form of an alternative dash board design, which, due to the extended nose of the vehicle design (see Figure 1) allowed the same space for additional services such as electronics and vehicle fluid bottles, whilst allowing visibility of the extra

window apertures below the windscreen. Figure 3b shows the redesigned FKA prototype, known as FKA iteration 2 in the project report [3]. Figure 3a shows the view from the driver's eyes demonstrating that the alternate dash board design was able to allow visibility of the additional window apertures below the windscreen.

2.3. DHM analysis methodology

The methodology for the analyses performed was developed to evaluate the visible areas adjacent to the test vehicles i.e. can something that should be seen by the driver using direct vision through the windows be hidden from the driver in a blind spot. This involves the projections of the visible volume of space from the eye point of the driver through the apertures of the vehicles. Anything that is inside the projections can be seen directly by the driver. Figure 4 shows an example where the driver of the HGV is looking through the passenger window. The head and shoulders of the cyclist can be seen by the driver, as illustrated by the head and shoulders being inside the window aperture projection.

The use of the project technique was combined with a number of target objects in order to explore blind spot size for each of the vehicles being tested. These were;

- Forward visibility: The visibility of a pedestrian(s) across the front of the assessment vehicle. Three pedestrian objects are positioned in line with the centre line of the vehicle and at each of the outer edges. This is designed to represent a pedestrian crossing in front of the test vehicle.
- The visibility of a cyclist(s) across the front of the assessment vehicle. Three cyclist objects are positioned in line with the centre line of the vehicle and at each of the outer edges. This is designed to represent a cyclist positioned at any point in front of the test vehicle, waiting at an advanced stopping area at a junction.
- The visibility of a cyclist(s) along the driver's and passenger's side of the vehicle. The cyclist is positioned fore-aft to align the top of their head with the driver's eye-point, (where used, a second cyclist is 1m in front of the first). This is designed to represent a cyclist either riding or waiting to the inside (nearest the pavement) of the vehicle.

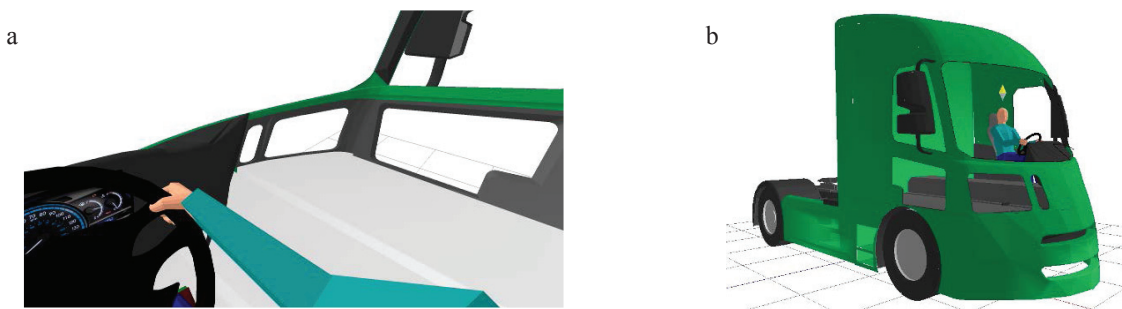


Fig. 3. (a) View through the driver's eye showing the additional window apertures (b) FKA concept iteration 2.

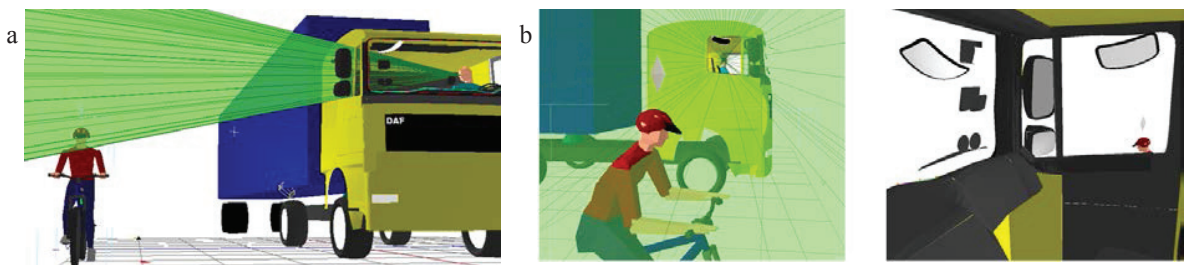


Fig. 4. (a) The projection from the drivers eyes through the windows. (b) the intersection of the cyclists head and shoulders with the projection. (c) the view through the driver's eyes of the cyclist's head.

These objects were placed adjacent to the vehicle and moved away from the vehicle to the maximum distance at which they could not be seen by the driver. This allows the size of the blind spots to be represented in terms of the distance away from the vehicle that the objects can be hidden. In some cases it is not possible to hide the objects from the field of view of the driver at any distance from the side of the vehicle. This technique has benefits over trying to determine what portion of a visual object is enough to be seen and recognised by a driver.

3. Results

3.1. Forward visibility of pedestrians

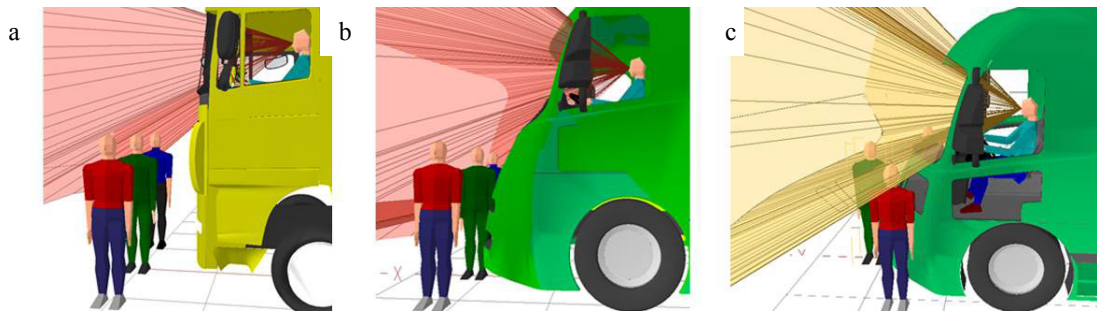


Fig. 5. (a) Pedestrian visibility for the DAF XF baseline vehicle (b) Pedestrian visibility for the FKA concept (c) Pedestrian visibility for the FKA concept iteration 2.

Table 1. The results for the forward visibility of pedestrians.

Visual object	Distance from the vehicle front	Distance from the vehicle front	Distance from the vehicle front
	DAF XF	FKA concept	FKA Concept iteration 2
Blue human	690mm	530mm	Visible
Green human	575mm	Visible	Visible
Red human	647mm	486mm	Visible

3.2. Forward visibility of cyclists



Fig. 6. (a) Driver's eye view of cyclist visibility for the DAF XF baseline vehicle (b) FKA concept (c) FKA concept iteration 2.

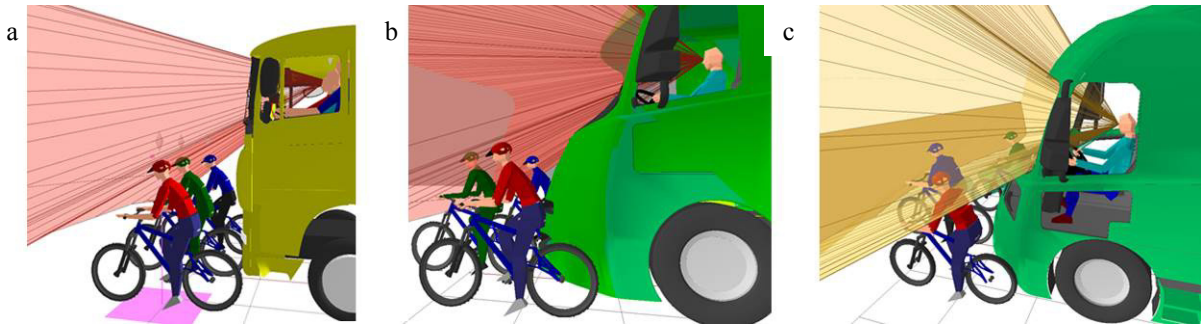


Fig. 7. (a) Cyclist visibility to the front of the DAF XF baseline vehicle (b) FKA concept (c) FKA concept iteration 2.

Table 2. The results for the forward visibility of cyclists.

Visual object	Distance from the vehicle front DAF XF	Distance from the vehicle front FKA concept	Distance from the vehicle front FKA Concept iteration 2
Blue cyclist	0	0	Visible
Green cyclist	Visible	Visible	Visible
Red cyclist	Visible	Visible	Visible

3.3. Passenger’s side visibility of cyclists

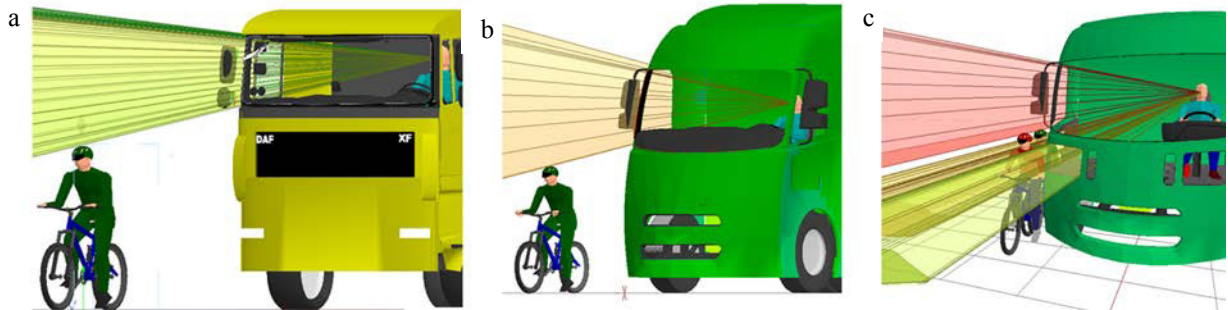


Fig. 8. (a) Cyclist visibility to the passenger side of the DAF XF baseline vehicle (b) FKA concept (c) FKA concept iteration 2

Table 3. The results for the passenger’s side visibility of cyclists.

Visual object	Distance from the vehicle side DAF XF	Distance from the vehicle side FKA concept	Distance from the vehicle side FKA Concept iteration 2
Passenger side cyclist	1903mm	1458mm	Visible

3.4. Driver's side visibility of cyclists



Fig. 9. (a) Cyclist visibility to the driver's side of the DAF XF baseline vehicle (b) FKA concept (c) FKA concept iteration 2.

Table 4. The results for the driver's side visibility of cyclists.

Visual object	Distance from the vehicle side DAF XF	Distance from the vehicle side FKA concept	Distance from the vehicle side FKA Concept iteration 2
Driver's side cyclist front	36mm	Visible	Visible
Driver's side cyclist rear	106mm	Visible	Visible

4. Discussion

4.1. Forward visibility of pedestrians

The results for the forward visibility of the pedestrians show that the benefit of the key design change to the vehicle, the addition of a curved protruding aerodynamic nose, pushes the middle (green) pedestrian further forward than is shown in the Baseline vehicle. This allows the middle pedestrian to be visible in the FKA concept but not with the baseline vehicle. The FKA concept iteration 2 allows all three pedestrians to be clearly visible due to its lower height than the other vehicles. The additional windows also support visibility of the blue pedestrian.

4.2. Forward visibility of cyclists

The results for the forward visibility of cyclists showed that all cyclists were visible for all vehicles, in that, in a location where the cyclists are touching the front of the vehicle, there was some part of the cyclist visible to the driver. However Figure 6 illustrates that for the Baseline vehicle only a small portion of the cyclists are visible and for the FKA concept only a small portion is visible for the left hand and right hand cyclists. For the FKA concept iteration 2 all cyclists are clearly visible. In reality cyclists would most likely have some clearance between themselves and a vehicle, moving them further forward, improving the view from the driver's position.

4.3. Passenger's side visibility of cyclists

The results for passenger side visibility of cyclists demonstrate that the Baseline and FKA concept vehicles exhibit extensive direct vision blind spots with the cyclist being 1903mm from the side of the Baseline vehicle and 1458mm from the side of the FKA concept. The FKA iteration 2 design allows visibility of cyclists to the passenger side for the defined test.

4.4. Driver's side visibility of cyclists

The results for the drive side visibility of cyclists demonstrate that the cyclists need to be in very close proximity to be obscured from the driver's vision for the baseline vehicle, and that the cyclists are visible for both FKA concepts.

4.5. General discussion of results

The key finding for the project was that the proposed design for the FKA concept only improves the direct vision ability of the driver in situations where VRUs are located centrally in front of the vehicle, with minor improvements to the driver's side when compared to the baseline vehicle. Blind spots still exist to both sides of the driver's cab. By reducing the height of the vehicle cab by 230mm, the driver's ability to directly view VRUs from FKA concept iteration 2 is greatly improved. The addition of a window below the passenger window improves the visibility of VRUs to the passenger side of the cab.

5. Conclusions

The research project has examined the design of a concept vehicle that is a likely outcome of the current discussions regarding revision of vehicle length standards in Europe. The design has been shown to have limited improvements in direct vision when compared to existing vehicles.

If direct vision is to be taken as a priority, as indicated by previous research, efforts should be directed towards producing vehicle designs with lower cabs for use in urban environments where VRUs are likely to be present. This could be supported by the definition of a direct vision standard for use by vehicle manufacturers which makes it clear what should be directly visible from a Category N₃ vehicle driving position. No such standard currently exists and this should be a priority for future research in this area.

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